Reports File

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OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: 12 April 1974

Project Title: Analysis of Samples

Project No: G-35-613

Principal Investigator Dr. J. M. Wampler

Sponsor: Law Engineering Testing Company; Charlotte, North Carolina

Agreement Period: From October 15, 1973 Until March 8, 1974

Type Agreement: Letter Dated March 8, 1974

Amount: $3,829.00

Reports Required: Technical Report Submitted

Sponsor Contact Person (s):

Mr. Donald G. Miller, Jr.
Law Engineering Testing Company
501 Minuet Lane
Charlotte, North Carolina 28209

Assigned to: Geophysical Sciences

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RA–3 (6–71)

Reports File

GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT TERMINATION

Date: October 1, 1974

Project Title: Analysis of Samples

Project No: G-35-613

Principal Investigator: Dr. J. M. Wampler

Sponsor: Law Engineering Testing Company; Charlotte, N. C.

Effective Termination Date: 3-14-74 (Technical Report submitted)

Clearance of Accounting Charges: N/A - all have cleared.

Grant/Contract Closeout Actions Remaining: None.

School of Geophysical Sciences

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RA-4 (5/70)

G-35-613

INTER OFFICE LETTER

LAW ENGINEERING TESTING COMPANY

December 10, 1973

To: LETCo.

From: J. M. Wampler

Reference: Analytical Procedures for Potassium-Argon Analysis

SAMPLE PREPARATION

Sample preparation procedures vary, depending on the nature of the individual samples. The report of analytical data will include notes on the preparation of each analytical sample.

One factor common to all samples is the need for two equivalent portions, one for potassium analysis and one for argon isotopic analysis. Therefore, all samples are crushed or otherwise disaggregated to a degree sufficient to insure that equivalent samples may be taken by standard splitting porcedures (i.e. by quartering or by use of a micro-splitter).

The two portions of each sample are weighed with a precision of ±0.1 mg. Occasionally, because of very small sample size or because of inhomogeniety within the sample, a significant uncertainty in the final $^{40}Ar/^{40}K$ ratio will arise from the splitting and weighing procedure.

POTASSIUM ANALYSIS

Samples are dissolved by hydrofluoric acid, with a small amount of perchloric acid added so that fluorides may be destroyed by evaporation of HF. Residual perchlorates are dissolved in a 4% HNO_3 solution containing 0.1% (by weight) NaCl as an ionization suppressant. The samples are diluted until the potassium concentration is less than 5 parts per million (by weight), with the sample concentration determined gravimetrically. Potassium content of the diluted solution is determined by atomic absorption spectrophotometry, by comparison with standard solutions of KCl. Precision of the method is such that the standard error is 0.5% or less. An absolute uncertainty of ±1% is estimated for all samples except those with less than 0.3% K, for which the uncertainty may be several percent.

ARGON ISOTOPIC ANALYSIS

Argon is release by melting the sample in vacuum. A "spike" of ^{38}Ar is added as an isotopic internal standard, at the beginning of the melting. After purification of the argon sample, a portion is transferred by equilibrium expansion into a mass spectrometer (MS-10) for isotopic analysis. After correction for atmospheric argon, based on the relative abundance of ^{36}Ar in the sample, the amount of radiogenic ^{40}Ar is determined from the ratio of ^{40}Ar to the ^{38}Ar internal standard.

When the percentage of atmospheric argon is less than 50% (most samples) the limits of error of the radiogenic ^{40}Ar measurement are estimated to be ± 2% of the value (subject to final calibration of the internal standard). A high percentage of atmospheric argon causes greater uncertainty.

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES
Atlanta, Georgia 30332
(404) 894-2857

February 28, 1974

Law Engineering Testing Company
501 Minuet Lane
Charlotte, North Carolina 28209

Gentlemen:

Enclosed are final potassium-argon analytical data on samples from site X-81A, submitted by Dan Maclemore, and samples from site X-81B, submitted since October 15, 1973 by Fred Stafford and Neil Gilbert. Data on sample DRP-125C are incomplete because of a failure of the vacuum system during the argon analysis of this sample. This analysis will be repeated upon request. Minimum values for the argon content and apparent age of D-16A are given, because of an irregularity in the argon analysis. A complete analysis of another portion of this sample was carried out, however.

A handwritten description of analytical procedures was submitted to Dan Maclemore in December. I have no copy of this, although it could be re-written if necessary. (I would appreciate your sending me a copy of the description if it is available.)

In the tables of analytical data I have included brief descriptions of each analytical sample. More detailed descriptions of the preparation of each sample are available in my notes, and are available to you upon request.

I do not have complete geological information about these samples, hence it would be inappropriate for me to attempt to interpret the geological significance of the potassium-argon ages. However, I do feel that some comments are in order, and I am including such comments on separate sheets for the two different sites.

Thank you for the opportunity to carry out this work for you.

Sincerely,

J. M. Wampler
Associate Professor

JMW:gh

Enclosure

SAMPLES FROM SITE X-81A

ANALYTICAL SAMPLE NUMBER	DESCRIPTION	POTASSIUM (Percent by weight)	RADIOGENIC ARGON (Percent of total argon)	RADIOGENIC ARGON (STP Nanoliters per gram)	APPARENT AGE (Millions of years)
D-A1-A	Fragments of diabase D-A1	0.202 ± 0.003	37.7	1.70 ± 0.09	200 ± 10
D-A1-AC	Coarse fraction of D-A1 after crushing	0.207 ± 0.003	70.9	1.67 ± 0.04	192 ± 5
D-A2BBW	Biotite from D-A2	5.85 ± 0.03	95.1	72.2 ± 1.5	286 ± 7
D-A3HBW	Pyroxene from D-A3	0.102 ± 0.003	73.6	1.96 ± 0.05	430 ± 15
D-A3MC	Hornblende from D-A3	0.394 ± 0.005	89.0	4.07 ± 0.08	243 ± 7
Samples from core #A-123					
A-123BT	Coarse biotite, away from sheared zone	6.68 ± 0.04	96.7	84.8 ± 1.7	294 ± 7
A-123MB	Fine, slightly altered biotite, away from sheared zone	6.88 ± 0.05	94.6	84.2 ± 1.7	284 ± 7
A-123SB	Fine biotite/vermiculite, from sheared zone	4.22 ± 0.04	61.1	38.6 ± 1.2	216 ± 7
A-123SMC	Fine biotite/vermiculite, from sheared zone. Lower density than A-123SB	2.45 ± 0.03	57.8	19.8 ± 0.6	192 ± 7
A-123SMCW	A-123SMC after heating in 1% HNO_3	2.34 ± 0.05	17.0	17.5 ± 1.5	179 ± 18
X-81A-15AEW	Heavy fraction of 15A (Almost all of sample went into heavy fraction)	0.139 ± 0.003	70.9	3.17 ± 0.09	499 ± 20
DRP-125C	DRP-125, coarse fraction after crushing	1.10 ± 0.01			
DRP-161HB	Hornblende from DRP-161 Small percentage other minerals	0.425 ± 0.003	95.2	5.79 ± 0.12	314 ± 8
DRP-242BM	Impure biotite and muscovite from DRP-242	4.48 ± 0.09	94.1	66.6 ± 1.4	340 ± 8
Samples from JTQ					
JTQ-1ML	Feldspar and chlorite	3.35 ± 0.02	88.5	27.0 ± 0.7	192 ± 6

SAMPLES FROM SITE X-81A - continued

ANALYTICAL SAMPLE NUMBER	DESCRIPTION	POTASSIUM (Percent by weight)	RADIOGENIC ARGON (Percent of total argon)	RADIOGENIC ARGON (STP Nanoliters per gram)	APPARENT AGE (Millions of years)
JTQ-1MM	Impure chlorite	1.36 ± 0.01	74.7	17.1 ± 0.5	290 ± 10
Samples from WFQI					
WFQI-1A	Chlorite from thick band	0.153 ± 0.003	12.1	1.70 ± 1.7	260 ± 30
WFQI-1ML	Feldspar and chlorite from thick chlorite band	0.700 ± 0.007	60.6	4.91 ± 0.12	168 ± 6
WFQI-1MH	Heavy fraction (chlorite, epidote) from thick chlorite band	0.202 ± 0.003	58.2	2.80 ± 0.08	319 ± 12
WFQ1-MV	Muscovite (somewhat impure) from WFQ1 (Second specimen)	6.78 ± 0.04	97.2	85.2 ± 1.8	291 ± 7
WFQII-M2W	Muscovite from WFQII	8.70 ± 0.05	97.5	110.1 ± 2.2	293 ± 7
D-16A	Diabase, 16A, crushed	0.208 ± 0.003	>61.1	>2.16	<244
D-16AC	Coarse fraction of D-16A	0.215 ± 0.003	71.4	2.33 ± 0.05	254 ± 10
D-18A	Diabase, 18A, crushed	0.158 ± 0.003	46.5	1.66 ± 0.05	246 ± 10
D-18AC	Coarse fraction of D-18A	0.159 ± 0.003	67.1	1.58 ± 0.04	234 ± 10
D-19A	Diabase, 19A, crushed	0.148 ± 0.003	50.7	1.43 ± 0.05	228 ± 10
D-19ACW	Coarse fraction of D-19A	0.143 ± 0.003	65.8	1.41 ± 0.04	232 ± 10

SAMPLES FROM SITE X-81B

ANALYTICAL SAMPLE NUMBER	DESCRIPTION	POTASSIUM (Percent by weight)	RADIOGENIC ARGON (Percent of total argon)	RADIOGENIC ARGON (STP Nanoliters per gram)	APPARENT AGE (Millions of years)
X-81B-1FR	Grace Mylonite #1	4.53 ± 0.03	95.6	28.5 ± 0.6	151 ± 4
X-81B-2A	Grace Mylonite #2	1.53 ± 0.01	74.5	9.59 ± 0.20	151 ± 4
X-81B-DA	Grace Dike #1	0.216 ± 0.003	37.4	1.69 ± 0.06	187 ± 7
X-81B-DAC	Coarse fraction of X-81B-DA	0.232 ± 0.003	51.3	1.77 ± 0.05	182 ± 6
BP-7BT	Biotite from BP-7, away from shear	6.74 ± 0.04	95.4	86.3 ± 1.8	296 ± 7
BP-7SB	Slickenside material from BP-7 [biotite plus alteration product(s)]	3.75 ± 0.08	86.3	40.3 ± 1.2	252 ± 10
B-28HBW	Hornblende from B-28, away from shear zone	0.248 ± 0.003	84.8	3.10 ± 0.07	290 ± 9
B-28SCH	Chlorite from shear zone of B-28	0.027 ± 0.003	24.0	0.51 ± 0.03	420 ± 50
X-81B-70A	Dibase #70	0.140 ± 0.003	64.0	1.37 ± 0.04	231 ± 10

COMMENTS ON POTASSIUM-ARGON APPARENT AGES

SAMPLES FROM SITE X-81A

Unaltered Micas: D-A2BBW, A-123BT, DRP-242BM, WFQ1-MV, and WFQII-M2W

Apparent ages of these samples should accurately date the time of cooling of the mica-bearing rock after crystallization or most recent metamorphism. Some samples were not highly purified, but it is not likely that the inpurities appreciably affected the measured Ar/K ratios.

Altered Micas: A-123MB, A-123SB, A-123SMC, and A-123SMCW

Weathering may lower the apparent age of mica by allowing argon to escape without complete removal of potassium. There is a progressive decrease in apparent age of samples from A-123, with decreasing density (increasing vermiculitization), which could be intrepreted as an effect of weathering alone. However, the rather distinct drop in apparent age between the unsheared and the sheared portion of the rock suggests that shearing may have affected the apparent ages. Since the acid treatment (A-123SMCW) did not change the apparent age of A-123SMC, it appears unlikely that weathering is the only factor affecting the apparent ages.

Diabases: D-A1-A, D-A1-AC, D-16A, D-16AC, D-18A, D-18AC, D-19A, and D-19ACW

Apparent ages of these samples should be approximately the time of intrusion of the diabase. One cannot be certain, however that the assumptions of the potassium-argon method are met in each case, without detailed studies (e.g. of chilled margins, contact metamorphised country rock, mineral separates from diabase).

Samples from D-A3: D-A3HBW and D-A3MC

The high apparent age of the pyroxene, D-A3HBW, is attributable to original (so-called "excess") radiogenic argon in the sample when it formed. Such original argon is not unusual in pyroxene of plutonic origin. Hornblende is less commonly affected by original argon, but one might be somewhat suspicious in this particular case.

Sample X-81A-15AEW:

The low potassium content of this sample suggests that original argon could significiently affect the apparent age. I suspect that the apparent age of this sample is meaningless in terms of the age of the rock.

Sample DRP-161HB:

A small percentage of K-feldspar in a hornblende sample could have a profound effect on the apparent age. Apparent ages from K-feldspar are typically well below that of co-genetic micas. I suspect that highly purified hornblende from DRP-161 would show an apparent age greater than 314 m.y.

Samples from JTQ: JTQ-1ML and JTQ-1MM

K-feldspar certainly predominates (in K-content) in JTQ-1ML and the 192 m.y. age is meaningless. It is likely that the K in JTQ-1MM is associated with impurities rather than the chlorite, so the meaning of the apparent age is in doubt.

Samples from WFQI: WFQI-1A, WFQI-1ML, WFQI-1MH

The low apparent age of WFQI-1ML is presumably related to the feldspar in the sample, although K-feldspar is absent or low in abundance. Uncertainties about the mineralogical composition of WFQI-1A and WFQI-MH are sufficient that there is little point in considering the slight differences between the apparent ages of these, and those of mica samples from related specimens.

COMMENTS ON POTASSIUM-ARGON APPARENT AGES
SAMPLES FROM SITE X-81B

Diabases: X-81B-DA, X-81B-DAC, and X-81B-70A

Apparent age of these samples should be approximately the time of intrusion of the diabase. One cannot be certain, however, that the assumptions of the potassium-argon method are met in each case, without detailed studies (e.g. of chilled margins, contact metamorphised country rock, mineral separates from diabase).

Mylonites: X-81B-1FR and X-81B-2A

Since plutonic K-feldspar typically gives K-Ar apparent ages considerably lower than the correct age, and since K-feldspar must be an important constituent of these samples, one must suspect that the 151 m.y. apparent age is too low in spite of the consistency between the two samples. It is conceivable, however, that the mylonitization may have changed the feldspar sufficiently both to re-set the K-Ar "clock" and to cause the feldspar to retain argon quantitatively. Study of mineral separates from these rocks may help determine what really happened.

Samples from BP-7: BP-7BT and BP-7SB

The apparent age of the unsheared biotite should give the time of cooling of the rock after crystallization or most recent metamorphism. The apparent age of the slickenside material, presumably influenced predominantly by the biotite therein, is most likely intermediate between the above age and the age of the shearing event. Conceivably, all of the argon could have been lost from the slickenside material during shearing, in which case the apparent age would give the time of shearing.

Samples from B-28: B-28HBW and B-28SCH

The apparent age of the hornblende presumably gives the time of cooling of the rock after crystallization or most recent metamorphism. The apparent age of the chlorite is almost certainly meaningless, because a very slight amount of original radiogenic argon in the chlorite would change the apparent age considerably.

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

June 10, 1974

Law Engineering Testing Company
Attn: Neil Gilbert
501 Minuet Lane
Charlotte, North Carolina 28209

Dear Neil:

Enclosed are two copies of the tables of potassium-argon analytical data for samples from sites X-81A and X-81B, to which have been added the amount of sample analysed, in each case, for potassium and for argon.

In going over these tables I have noted a typographical error which should be corrected. The apparent age of sample D-16A should be given as >244 m.y. I have made this correction on the enclosed copies of the tables.

The explanation for the difference between the preliminary and final data is as follows:

Preliminary argon data were generally based on a quick reading by eye of the strip chart output of the mass spectrometer, using only a single scan of the argon mass spectrum. Final data were based on an accurate measurement of at least two scans. Preliminary potassium data were generally based on a single comparison of the absorbance of the dissolved sample against standard solutions. Final data were based on repeated comparisons, in order to reduce the statistical error. For these reasons, the final data are generally slightly different from the numbers reported on a preliminary basis, and the uncertainties assigned the final ages are generally less than those assigned to the preliminary values. (In one case, sample WFQII-M2W, there was a mistake in the preliminary report.)

Shortly, I shall send the information you have requested about the nature of the individual analytical sample materials.

Sincerely,

J. M. Wampler
Associate Professor

JMW:gh

Enclosure

ANALYTICAL SAMPLE NUMBER	DESCRIPTION	POTASSIUM (Percent by weight)	K Analysis	RADIOGENIC ARGON (Percent of total argon)	RADIOGENIC ARGON (STP Nanoliters per gram)	Argon Analysis	APPARENT AGE (Millions of years)
D-A1-A	Fragments of diabase D-A1	0.202 ± 0.003	0.3887	37.7	1.70 ± 0.09	0.4797	200 ± 10
D-A1-AC	Coarse fraction of D-A1 after crushing	0.207 ± 0.003	0.5283	70.9	1.67 ± 0.04	0.6168	192 ± 5
D-A2BBW	Biotite from D-A2	5.85 ± 0.03	0.1407	95.1	72.2 ± 1.5	0.1220	286 ± 7
D-A3HBW	Pyroxene from D-A3	0.102 ± 0.003	0.1621	73.6	1.96 ± 0.05	0.3149	430 ± 15
D-A3MC	Hornblende from D-A3	0.394 ± 0.005	0.1470	89.0	4.07 ± 0.08	0.2695	243 ± 7
Samples from core #A-123							
A-123BT	Coarse biotite, away from sheared zone	6.68 ± 0.04	0.0596	96.7	84.8 ± 1.7	0.0744	294 ± 7
A-123MB	Fine, slightly altered biotite, away from sheared zone	6.88 ± 0.05	0.0259	94.6	84.2 ± 1.7	0.0594	284 ± 7
A-123SB	Fine biotite/vermiculite, from sheared zone	4.22 ± 0.04	0.0172	61.1	38.6 ± 1.2	0.0149	216 ± 7
A-123SMC	Fine biotite/vermiculite, from sheared zone. Lower density than A-123SB	2.45 ± 0.03	0.0184	57.8	19.8 ± 0.6	0.0300	192 ± 7
A-123SMCW	A-123SMC after heating in 1% HNO_3	2.34 ± 0.05	0.0063	17.0	17.5 ± 1.5	0.0061	179 ± 18
X-81A-15AEW	Heavy fraction of 15A (Almost all of sample went into heavy fraction)	0.139 ± 0.003	0.3587	70.9	3.17 ± 0.09	0.6427	499 ± 20
DRP-125C	DRP-125, coarse fraction after crushing	1.10 ± 0.01	0.3403				
DRP-161HB	Hornblende from DRP-161 Small percentage other minerals	0.425 ± 0.003	0.3954	95.2	5.79 ± 0.12	0.4041	314 ± 8
DRP-242BM	Impure biotite and muscovite from DRP-242	4.48 ± 0.09	0.0153	94.1	66.6 ± 1.4	0.0343	340 ± 8
Samples from JTQ							
JTQ-1ML	Feldspar and chlorite	3.35 ± 0.02	0.0369	88.5	27.0 ± 0.7	0.0421	192 ± 6

ANALYTICAL SAMPLE NUMBER	DESCRIPTION	POTASSIUM (Percent by weight)	K Analysis	RADIOGENIC ARGON (Percent of total argon)	RADIOGENIC ARGON (STP Nanoliters per gram)	Argon Analysis	APPARENT AGE (Millions of years)
JTQ-1MM	Impure chlorite	1.36 ± 0.01	0.0397	74.7	17.1 ± 0.5	0.0384	290 ± 10
Samples from WFQI							
WFQI-1A	Chlorite from thick band	0.153 ± 0.003	0.0452	12.1	1.70 ± 1.7	0.0892	260 ± 30
WFQI-1ML	Feldspar and chlorite from thick chlorite band	0.700 ± 0.007	0.0651	60.6	4.91 ± 0.12	0.1578	168 ± 6
WFQI-1MH	Heavy fraction (chlorite, epidote) from thick chlorite band	0.202 ± 0.003	0.0734	58.2	2.80 ± 0.08	0.0831	319 ± 12
WFQ1-MV	Muscovite (somewhat impure) from WFQ1 (Second specimen)	6.78 ± 0.04	0.0483	97.2	85.2 ± 1.8	0.0559	291 ± 7
WFQII-M2W	Muscovite from WFQII	8.70 ± 0.05	0.0900	97.5	110.1 ± 2.2	0.0882	293 ± 7
D-16A	Diabase, 16A, crushed	0.208 ± 0.003	0.3228	>61.1	>2.16	0.3429	>244
D-16AC	Coarse fraction of D-16A	0.215 ± 0.003	0.4740	71.4	2.33 ± 0.05	0.4362	254 ± 10
D-18A	Diabase, 18A, crushed	0.158 ± 0.003	0.2025	46.5	1.66 ± 0.05	0.2203	246 ± 10
D-18AC	Coarse fraction of D-18A	0.159 ± 0.003	0.2554	67.1	1.58 ± 0.04	0.2759	234 ± 10
D-19A	Diabase, 19A, crushed	0.148 ± 0.003	0.2284	50.7	1.43 ± 0.05	0.2150	228 ± 10
D-19ACW	Coarse fraction of D-19A	0.143 ± 0.003	0.3455	65.8	1.41 ± 0.04	0.3097	232 ± 10

SAMPLES FROM SITE X-81B (grams)

ANALYTICAL SAMPLE NUMBER	DESCRIPTION	POTASSIUM (Percent by weight)	K Analysis	RADIOGENIC ARGON (Percent of total argon)	RADIOGENIC ARGON (STP Nanoliters per gram)	Argon Analysis	APPARENT AGE (Millions of years)
X-81B-1FR	Grace Mylonite #1	4.53 ± 0.03	0.3516	95.6	28.5 ± 0.6	0.3039	151 ± 4
X-81B-2A	Grace Mylonite #2	1.53 ± 0.01	0.1397	74.5	9.59 ± 0.20	0.1535	151 ± 4
X-81B-DA	Grace Dike #1	0.216 ± 0.003	0.4267	37.4	1.69 ± 0.06	0.4108	187 ± 7
X-81B-DAC	Coarse fraction of X-81B-DA	0.232 ± 0.003	0.2810	51.3	1.77 ± 0.05	0.2556	182 ± 6
BP-7BT	Biotite from BP-7, away from shear	6.74 ± 0.04	0.0399	95.4	86.3 ± 1.8	0.0433	296 ± 7
BP-7SB	Slickenside material from BP-7 [biotite plus alteration product(s)]	3.75 ± 0.08	0.0146	86.3	40.3 ± 1.2	0.0187	252 ± 10
B-28HBW	Hornblende from B-28, away from shear zone	0.248 ± 0.003	0.4004	84.8	3.10 ± 0.07	0.4345	290 ± 9
B-28SCH	Chlorite from shear zone of B-28	0.027 ± 0.003	0.0492	24.0	0.51 ± 0.03	0.0534	420 ± 50
X-81B-70A	Dibase #70	0.140 ± 0.003	0.4304	64.0	1.37 ± 0.04	0.4542	231 ± 10

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

June 19, 1974

Law Engineering Testing Company
P. O. Box 11297
Charlotte, N. C. 28209
Attn: Neil J. Gilbert

Dear Neil:

Enclosed are two copies of a memorandum describing the preparation of analytical samples for potassium-argon analysis, from rock samples from sites X-81A and X-81B. These notes indicate my observations of possible weathering effects in some specimens, and also give my estimate of the mineralogical composition of each analytical sample, except in some cases where my laboratory notes are incomplete and the analytical sample is no longer on hand. (These samples were, I believe, turned over to Dan MacLemore along with the remaining portions of the original rock specimens.)

Sincerely,

J. M. Wampler
Associate Professor

xc: Office of Research Administration, Georgia Tech

GEORGIA INSTITUTE OF TECHNOLOGY

SCHOOL OF GEOPHYSICAL SCIENCES

Atlanta, Georgia 30332
(404) 894-2857

June 18, 1974

MEMORANDUM

TO: Law Engineering Testing Company, Charlotte

FROM: J. M. Wampler

SUBJECT: Notes on Sample Preparation for Potassium-Argon Analysis

A. SAMPLES FROM SITE X-81A

Unaltered Micas

D-A2BBW: Acid-washed heavy fraction from pulverized fresh rock sample D-A2, size range 0.25-0.5 mm. Analytical sample is about 80% biotite with epidote and unidentified heavy minerals making up most of remainder. Traces of quartz and feldspar occur in aggregate grains.

A-123BT: Acid-washed heavy fraction ($3.3>\rho>2.96$) from a pulverized sample of core A-123, 99.7'-101.7'. This sample was from fresher portion of core, about 2" from 99.7' level, but showing some weathering (faint iron stain around biotite, rather easily broken). Weathered material was mostly eliminated by ultrasonic disaggregation and decantation of fine material. Size range of final analytical sample is 0.25-1.0 mm; sample is >95% biotite with most impurities present as aggregate grains. Some of the biotite flakes show superficial iron oxide.

A-123MB: Biotite separated from decanted fine fraction of pulverized rock from which A-123BT, above, was separated. Analytical sample was prepared by taking a heavy fraction ($3.3>\rho>2.90$), sieving to remove particles <0.12mm, and otherwise improving biotite content to 90-95%. Impurities are unidentified.

This sample was originally reported as slightly altered, because of a misinterpretation of the density range. The sample shows no alteration apparent under the microscope.

DRP-242BM: Impure mica fraction from rock sample DRP-242. Analytical sample is 10-20% biotite, showing some iron oxide stains, and perhaps 50% muscovite. Impurities are unidentified, but may be largely feldspar.

WFQ1-MV: Muscovite concentrate from muscovite-rich zone of rock WFQ1 (2nd specimen). Analytical sample is about 75% muscovite with chlorite and unidentified colorless minerals as impurities.

WFQII-M2W: Acid-washed, high-purity (>98%) muscovite from muscovite-rich zone of rock specimen WFQII.

Altered Micas

A-123SB: Concentrate of altered biotite from sheared zone of core A-123, 99.7'-101.7'. After pulverization and ultrasonic disaggregation, nearly all biotite was in fine fraction separated by decantation. Biotite was concentrated by sieving to eliminate particles <0.12mm and by heavy liquids. For this sample, $2.9>\rho>\approx 2.7$. Analytical sample is about 90% vermiculitic biotite with a few grains of dark, apparently unaltered biotite. Impurities are unidentified.

A-123SMC: Concentrate of lower density biotite/vermiculite from same pulverized rock sample as A-123SB, above. Density is less than ≈2.7 and size is >0.12mm. Analytical sample is >95% biotite/vermiculite with unidentified impurities.

A-123SMCW: A portion of A-123SMC heated gently in 1% HNO_3 for about one hour.

Diabases

D-A1-A: Acid washed fragments from unaltered central portion of rock sample D-A1. Fragments, mostly 1-2mm in size were broken from a saw cut slice of the rock. (The large size of these fragments may have introduced some "sampling error" in the potassium-argon ratio.)

D-A1-AC: Acid washed fragments from a pulverized portion of D-A1-A, with finest fragments removed by decantation. Approximate size range is 0.03-1mm.

D-16A: A pulverized (to less than about 1mm) portion of rock sample D-16 taken as far as possible from weathered surface. No alteration of analytical sample is apparent.

D-16AC: A portion of D-16A with finest material removed by decantation.

D-18A: A pulverized (to less than about 1mm) portion of rock sample D-18, taken well away from weathered surface.

D-18AC: A portion of D-18A with finest material removed by decantation.

D-19A: A pulverized (to less than about 1mm) portion of rock sample D-19, taken from a tough piece of the specimen, away from apparent alteration.

D-19ACW: An acid washed portion of D-19A, with finest material removed by decantation.

Other Samples

D-A3HBW: An acid washed heavy fraction ($3.3>\rho>\approx 3.1$) from a pulverized (to <0.5mm) portion of rock sample D-A3. Fine material was removed by decantation. The analytical sample is a highly pure (>99%) mixture of a light green mineral, presumed to be pyroxene, and a darker green mineral, presumed to be hornblende. The latter constitutes only 10-20% of the sample.

D-A3MC: An acid washed fraction of pulverized rock sample D-A3, selected by size (0.35-5mm) and density (undetermined, but probably about 3.1) to be as rich as possible in hornblende. Feldspar in aggretate grains was mostly removed by hand-picking.

X-81A-15AEW: An acid washed heavy fraction (ρ>2.96) of a pulverized portion of rock sample 15A. There was some superficial alteration of the material pulverized. Even in the finer material (0.03-0.35mm) the density separation was ineffective because of intimate intergrowth of heavy and light minerals. The analytical sample is little different in composition from the whole rock.

DRP-161HB: An acid washed heavy fraction (3.3>ρ> 2.96) of pulverized rock sample DRP-161. The sample crushed very easily, suggesting some alteration. Fine material was removed by decantation. A magnetic technique was used to enrich the hornblende of the final analytical sample.

JTQ-1ML: A light fraction (ρ<≈2.7) from the chlorite band of rock specimen JTQ. Taken from an approximate size cut (0.03-0.2mm) after gentle crushing and ultrasonic disaggregation of a portion of the chlorite band.

JTQ-1MM: An intermediate density fraction (2.9>ρ>≈2.7) of the same material from which JTQ-1ML, above, was separated. Mostly chlorite with possibly some biotite, and unidentified impurities.

WFQI-1A: An intermediate density fraction (2.9>ρ>≈2.7) from the chlorite band of rock WFQI (1st specimen). Taken from an approximate size cut (0.06-0.2mm) after gentle crushing and ultrasonic disaggregation of a portion of the chlorite band. Mostly chlorite.

WFQI-1ML: A light fraction (ρ<≈2.7) of the same material from which WFQI-1A, above, was separated. Feldspar and chlorite.

WFQI-1MH: A heavy fraction (ρ>2.9) of the same material from which WFQI-1A, above, was separated. Chlorite and epidote.

B. SAMPLES FROM SITE X-81B

Diabases

X-81B-DA: Acid washed fragments, 1-4mm in size, from a saw cut slice through tough inner core of rock specimen X-81B, Grace Dike #1. No alteration is apparent in the inner core, from which the fragments were taken. (The large size of these fragments may have introduced some "sampling error" in the potassium-argon ratio.)

X-81B-DAC: Acid washed fragments from a pulverized portion of X-81-B-DA with finest fragments removed by decantation. Approximate size range is 0.03-1mm.

X-81B-70A: An acid washed, pulverized portion of diabase #70, taken from a saw cut slice, avoiding weathered surfaces, and with finest fragments removed by decantation. Approximate size range is 0.03-1mm.

Mylonites

X-81B-1FR: A pulverized (to $<$ 0.5mm) portion of Grace Mylonite #1, selected from the freshest large fragments of the rock after crushing with hammer. These fragments were quite tough, and thus apparently not much altered by weathering.

X-81B-2A: A pulverized (to $<$0.5mm) portion of Grace Mylonite #2, selected from the freshest large fragments of the rock after crushing with hammer. There was a little manganese stain on these fragments, but they appeared otherwise to be unaltered.

Other Samples

BP-7BT: An acid washed biotite concentrate from 59.7 ft. level of core BP-7, taken from end of core specimen as far as possible from the fault at about 59 ft. This piece of the core was pulverized to $<$0.35mm and fines were removed by decantation. The biotite concentrate is an intermediate density fraction ($2.96>\rho>2.90$) enriched by rolling on waxed paper. Product is about 95% biotite with unidentified impurities.

BP-7SB: Biotite-rich material from the slickensided surface of the fault in core BP-7, 58.8-59.7 ft. Great care was taken to avoid material not part of the slickensides. Material was gently crushed and ultrasonically disaggregated, with finest material discarded by decantation.

B-28HBW: An acid washed hornblende concentrate from the unsheared end of core B-28,105.4-106.0 ft. There are some small fractures in this end, filled with secondary material, but the percentage of secondary material is small. After breaking with a hammer, pieces were selected which were essentially free of alteration. The hornblende concentrate is a heavy fraction ($\rho \gtrsim 3.1$) of the pulverized sample, in the approximate size range 0.03-0.35mm. Product is about 98% hornblende, with unidentified impurities.

B-28SCH: A heavy fraction ($\rho \approx 2.9$) from the chloritic slickensides of the fault in core B-28,105.4-106.0 ft. From gently crushed and untrasonically disaggregated pieces of the slickenside material. Approximate size range 0.06-0.2mm. High purity chlorite.

C. ADDITIONAL NOTES

1. Unless otherwise indicated, "acid washed" means sample was heated gently in approximately 1% HNO_3 for about 1 hour.

2. If there are no comments on the state of alteration of a specimen, the specimen was apparently unaltered by weathering.

3. My data on the mineralogical composition of some of the analytical samples are incomplete, because these samples were turned over to LETCO for possible mineralogical analysis elsewhere.